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# A Solution in Search of Problems

Magnetic fluids with unusual properties and far-reaching potential exemplify the scope and value of aerospace spinoff

Chances are you've never heard of ferrofluids; few people have. Yet ferrofluids—magnetic liquids whose unusual properties offer unique advantages in a wide range of applications—represent an emerging technology of such exciting promise it seems likely to spur development of a whole new industry.

Ferrofluids had their genesis in the early days of the U.S. space program. NASA faced a problem: how to feed fuel to the engine of an orbiting spacecraft when the fuel—like everything else in orbit—is weightless. A scientist at Lewis Research Center hit upon the idea of imparting magnetic properties to the fuel by dispersing within it finely ground iron oxide particles; the fuel

could then be drawn into the engine by a magnetic source. Ultimately, NASA solved the problem by a different approach and ferrofluid research was shelved for the moment—but the Lewis investigations had planted the seed of a new technology.

Ferrofluids surfaced again in the mid-sixties. At Avco Space Systems Division, scientists were working on another space problem: how to control the temperature of a spacecraft which is very hot on the side facing the Sun and very cold on the other side. Applying their own expertise and drawing on the earlier NASA technology, they came up with a concept wherein a magnetic field would draw ferrofluid through a

pipe-ring around the spacecraft, cooling the hot side and warming the cold surface. Once again an alternative solution was found and the operational debut of ferrofluids was delayed.

But not for long. Two of the Avco scientists—Dr. Ronald Moskowitz and Dr. Ronald Rosensweig—realized that ferrofluids offered vast problem-solving potential. Armed with a license for the NASA technology, which served as a departure point for their own further development of ferrofluids, they left Avco in 1969 and formed Ferrofluidics Corporation, Nashua, New Hampshire. Says company president Moskowitz: "We had no products and no customers. We were a company with a solution looking for a problem."

In their first year, they found a problem they could solve, one related to the manufacture of semiconductor "chips" for use in electronic systems. In semiconductor production, aluminum is deposited on silicon wafers within a vacuum chamber. The chamber must be perfectly sealed, since even the most minute exposure to air can destroy the aluminum's conductivity and make the chip useless. Sealing requirements are complicated by the fact that the silicon wafers must be rotated to get even distribution of the aluminum deposit. Thus, the seal must reliably accommodate a rotating shaft into the vacuum



other contaminants. The seal is virtually wear-proof and has a lifetime measured in billions of shaft revolutions; it affords substantially reduced maintenance, minimizes "downtime" of production equipment, and significantly reduces the cost of expensive materials once lost through seal failures.

From that start, Ferrofluidics expanded rapidly into many other applications. Among products based

*Dr. Ronald Moskowitz, president of Ferrofluidics Corporation, displays some of his company's products. Ferrofluid—magnetic liquid—represents a new technology of exceptional promise in a great variety of practical applications.*



chamber. This factor caused frequent chamber leakage induced by wear and breakdown of commonly used seals.

Ferrofluidics' answer was a magnetic seal composed of ferrofluid and a magnetic circuit. The magnetic field confines the ferrofluid in the regions between the stationary elements and the rotary shaft of the seal. The result is a series of liquid barriers that totally bar passage of vapor, mist, gas, lubricants, dirt or

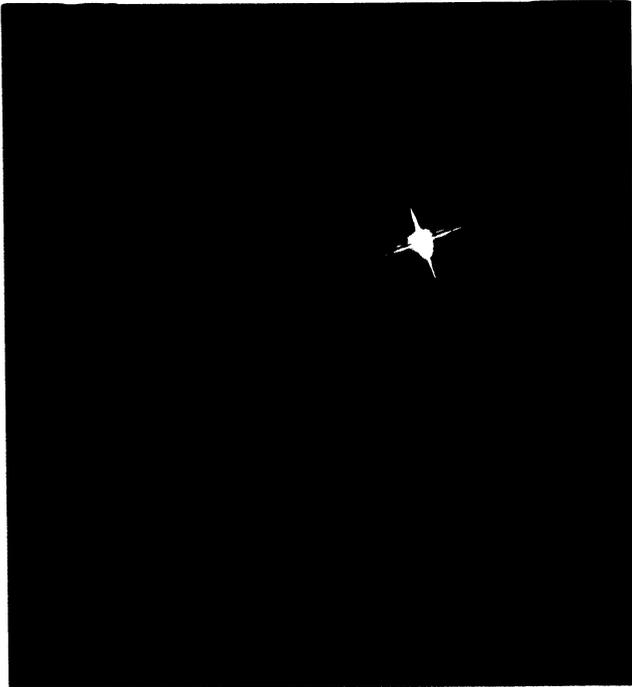
on ferrofluid are exclusion seals for computer disc drives and inertia dampers for stepper motors. Ferrofluids are also used as performance-improving, failure-reducing coolants for hi-fi loudspeakers. They are finding growing acceptance in a variety of industrial processes, analytical instrumentation, medical equipment, silicon crystal growing furnaces, plasma processes, fusion research, visual displays and automated

machine tools. And that's only the beginning. Dr. Moskowitz sees an "awesome" range of potential applications, from artificial heart pumps to cleaning up oil spills.

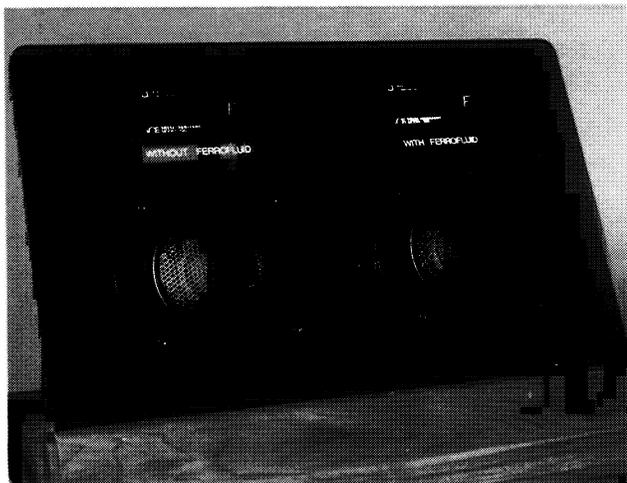
From a sales volume of \$65,000 in its first year, Ferrofluidics has expanded to annual sales in the multimillions and expects to top the \$100 million level within the decade. Now a multidivisional company with European and Japanese subsidiaries, it rapidly outgrew its first plant and is already overseeing expansion of its new, considerably larger facility. Ferrofluidics is the sole production source for ferrofluids and ferrofluid systems, but there is growing interest in the broad potential of magnetic fluid technology. Says Ronald Moskowitz: "What the NASA technology launched was not just a single company but probably a whole new industry."

The Ferrofluidics story is an outstanding example of the aerospace spinoff process. It shows the universality of spinoff—how a technology originated to meet aerospace needs can be reapplied in many ways remote from the original application. It also underlines the economic potential of spinoff; as happens frequently, this technology transfer resulted in establishment of an entirely new company, with attendant benefit to the nation's Gross National Product and job creation. Spinoffs whose benefits are valued in the millions of dollars are not unusual. In other cases, spinoffs generate only moderate economic gain, but provide significant public benefits in other ways, ranging from simple conveniences to important developments in medical and industrial technology.

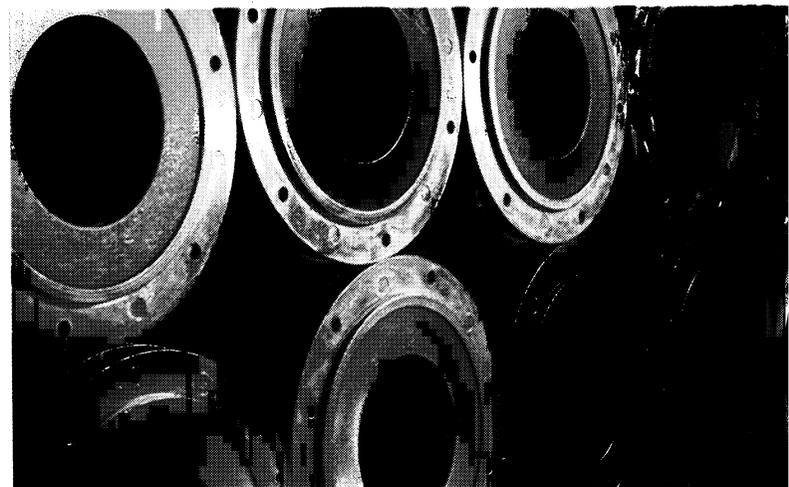
For almost two decades, under its Technology Utilization Program, NASA has been actively engaged in promoting the secondary application of aerospace technology. During that time, thousands of innovations originating in aerospace research have found their way into everyday use. Collectively, these spinoffs represent a substantial return on the aerospace investment in terms of economic gain, improved industrial efficiency and productivity, lifestyle innovations, and solutions to problems of public concern.



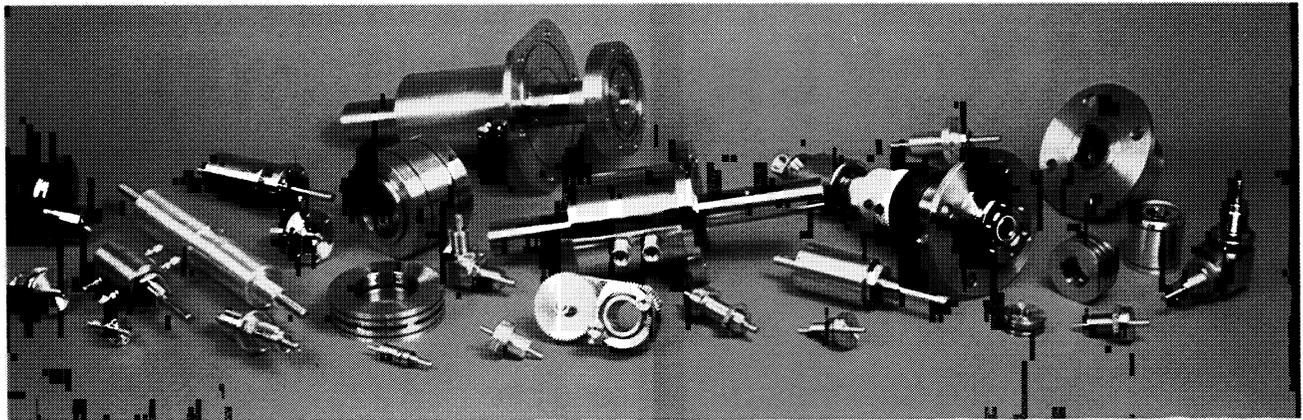
*Above, ferrofluid is being pulled in two directions by two magnetic fields. It illustrates how the fluid—which contains freely-suspended submicroscopic iron oxide particles—can be positioned and controlled by a magnetic source. This capability offers many unusual useful applications. The “spiking” phenomenon shown in close-up at right is caused by the energy balance between magnetic forces and surface tension.*



*This photo illustrates the efficiency of ferrofluid used as a coolant in hi-fi loudspeakers. At left is a conventional speaker. Ferrofluid was injected into the voice coil segment of the speaker at right. The digital readouts show the relative temperatures: 228 degrees Fahrenheit for the conventional unit, only 85 for the speaker containing ferrofluid. Effective cooling of the voice coil substantially increases the loudspeaker system's ability to handle higher power levels and decreases the chance of speaker failure.*



*A major Ferrofluidics product is an exclusion seal for computer disc drives, which are highly susceptible to contamination; a tiny mote of dust, one-tenth the diameter of a human hair, can damage the disc head and cause loss of the data in the disc's memory. More than a score of computer equipment manufacturers are using Ferrofluidics' seals, which have proved highly effective in protecting stored information.*



*Ferrofluidics recently extended magnetic fluid technology into a new area with the addition to its product line of a system for improving the operation of silicon crystal growing furnaces. Single crystal silicon is the key starting material for solar cells and semiconductor chips. The company's crucible lift system shown lifts and rotates a crucible of molten silicon during the crystal growing process. The highly precise mechanical device permits higher productivity and purer silicon by reducing vibration and contamination.*

*Among products manufactured by Ferrofluidics Corporation are rotary seals, in which a magnetic circuit controls ferrofluid to form wear-proof liquid barriers that totally block passage of contaminants into sealed vacuum chambers. The company now offers a large line of seals, produced by its Vacuum Technology Division. Ferrofluidics® also has Computer Products and Audio Products Divisions.*

*®Ferrofluidics is a registered trademark of Ferrofluidics Corporation.*



*Ferrofluid offers an effective medium for damping—reducing unwanted vibration—in “stepper” motors, used in such systems as plotters, computer printers, motion picture duplicators, and machine tools. In the photo above is the company's family of Ferrofluidic Inertia Dampers.*